Welcome to the EUFN Workshop 2022
Abstract Submission

Please select your presentation preference

☑ *Oral presentation*

☐ *Poster presentation*

- Please convert your abstract as PDF document and send it to:

  robert.winkler@felmi-zfe.at

- For easier handling, please write **EUFN 2022 Abstract** in the subject.
- For your convenience, you can check the tag DELIVERY RECEIPT in your email program.

Focused Ion Beam Induced Strain Generation in Silicon Membranes

D. C. Cox*, and M.G. Masteghin

National Ion Beam Centre, University of Surrey, Guildford Surrey, GU2 7XH, U.K.
* corresponding author email d.cox@surrey.ac.uk

In this presentation we show an incredibly simple and controllable way of generating strain in suspended Si membranes using a Focused Ion Beam. The strain we observe approaches record levels observed in this material while retaining high crystallinity[1].

What this study also shows however is the power of serendipity. Without doubt the work contained here would not have occurred were it not for very substantial luck. The FIB induced strained region does not occur in the ion irradiated regions but in the non-irradiated regions adjacent to it. It was only possible to observe this effect due to presence of existing compressive stress, leading to buckling, in our 35 nm thick membrane substrates. This combined with an experiment that required us to irradiated them with a 30 kV ion beam led to the phenomena reported here.

FIB Irradiation of samples with energetic ion beams can create many effects such as doping, sputtering, chemical modification and damage creation. These effects depend greatly on ion energy, dose and species. The creation of damage and/or amorphisation due to the implantation of energetic ions is well understood and none more so than in the silicon system due its prominence in the semiconductor industry. For a normal incidence Ga ion at 30 kV the average ion range can be calculated to be approximately 25 nm deep, or a little less for an equivalent energy Xe ion. In both cases full amorphisation of the Si to a depth of the ion range occurs at less than 4 e14 ions/cm^2. For a focused ion beam to achieve doses of this intensity is trivial taking only a few seconds even at modest beam currents.

If 20 kV Ga ions or 30 kV Xe ions are implanted into a 35 nm thick Si membrane the ion range and hence crystal amorphisation corresponds to very close to the midpoint of the membrane thickness. This creates a bi-layer system that induces bending of the implanted membrane regions straining the adjacent unimplanted regions. Using simple FIB patterning strategies and exploiting crystal anisotropy we have shown it is possible to create biaxial strain in excess of 3% and uniaxial in excess of 8%. If the same technique were applied to germanium a transition to a direct band-gap semiconductor could be achieved at equivalent strains.

[1] Stress-strain engineering of single-crystalline silicon membranes by ion implantation: Towards direct-gap group-IV semiconductors

M.G. Masteghin, V. Tong, E.B. Schneider, C.C. Underwood, T. Peach, B. N. Murdin, R.P. Webb, S.K. Clowes and D.C. Cox. Physical Review Materials, Vol.5, 124603. 2021

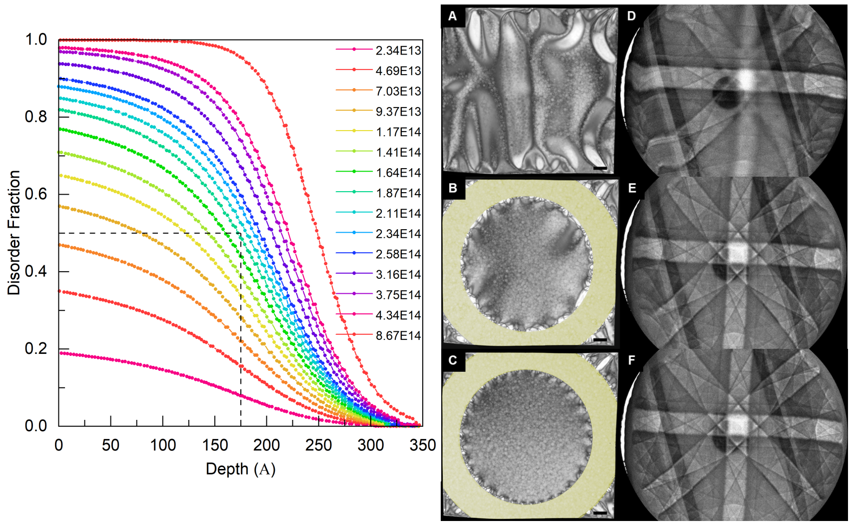

Fig. 1: (Left hand panel) Disorder fraction vs depth for 30 kV Xe ions into Si for the dose range 2.4 e13 to 8.7 e14 ions/cm^2 showing how the irradiated side of the membrane becomes amorphous but the lower side remains undamaged. (Right hand panel) The Si membrane prior to implantation (A), after partial exposure of the annular pattern, false coloured in yellow (B) and the same sample at a higher dose where the membrane buckles have been removed (C). The diffraction patterns demonstrate how the central region of the membrane is pulled flat but retains its crystallinity. The inner annular diameter is 80 μm.